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FARM DRAINAGE PRACTICE

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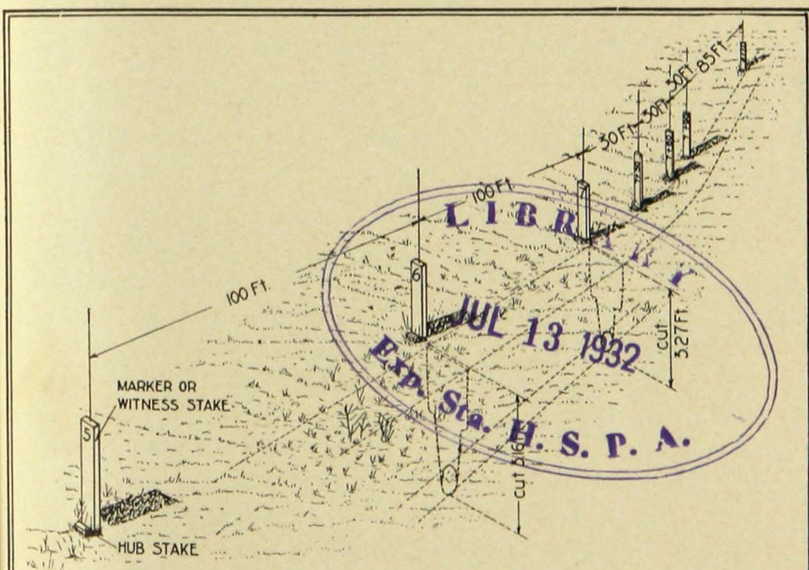

The right way to stake out a tile drain.

UNIVERSITY OF MINNESOTA
AGRICULTURAL EXTENSION DIVISION

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RELATION OF DRAINAGE TO FARMING

Drainage of wet spots in cultivated fields results in increased crops of better quality, makes it possible to "square up" fields so that they can be cultivated with a minimum of time and labor, and allows more timely seeding and cultivation. A delay of a single week in seeding sometimes means from 10 to 50 per cent less yield. From 1/5 to 1/3 of all the land even in well established Minnesota farms is too wet in years of normal rainfall for most efficient production of crops. Modern labor saving machines can not be used effectively on fields cut up by wet spots. Tilling poorly drained land is very discouraging. When, owing to poor drainage, no crop is harvested after plowing, planting, and cultivating, there is a loss of labor, fertilizer, seed, and the rental value of the land.

In the best soil moisture condition for plant growth, the pore spaces in the soil are 4/5 filled with water and 1/5 with air. Air is just as essential for the roots as for the leaves. The roots of ordinary crop plants will not penetrate a saturated soil. Instead of penetrating to a depth of 3 or 4 feet, as most of them would do in a well drained soil, roots mature early in the upper few inches. Here the plant food is soon exhausted and the plant becomes stunted or dies. Good drainage prevents this by stimulating deep rooting.

IMPORTANCE OF PLANNING A DRAINAGE SYSTEM

Essentials.—A drainage system, like a house, should be planned before it is built. The plan, which should be complete even tho but a few lines are put in at a time, should be made by an engineer trained to design and install drainage. A proper design is influenced by the six following factors: The outlet, its capacity and depth below the area to be drained; the watershed, its area, character of surface, and shape; the rate of fall obtainable; the character of soil and subsoil; the rainfall, its amount, frequency, and distribution; and the purpose of the drainage system. These factors and their inter-relationships are seldom understood by either the farmer or the tiler. They are, however, fully understood by the engineer.

Importance of the outlet.—A drainage system is useless without an outlet. The depth of the outlet below the mouth of the main and its capacity are of first importance and these points are easily determined. The ideal outlet allows continually for free fall and flow away from the main, a good fall in the main, and a depth of main just sufficient properly to receive the flow from all laterals.

The watershed.—Merely to know the area of wet land in a drainage basin is of little value in determining the size of outlet needed. The watershed is an irregular funnel, the spout of which is the outlet drain that must eventually pass all the excess water that falls within the rim. How fast the water will accumulate at the spout largely depends on whether the watershed is long and narrow with steep slopes or broad and flat; whether the surface is rough or smooth; whether it is bare or covered with plant growth; and how readily the surface soil absorbs the water running over it. Hence it is necessary to know the area, shape, and surface condition of the watershed.

Rate of fall.—The steeper a given slope the faster water tends to run down it, hence the amount of water a given tile will carry largely depends upon the rate of fall in the tile line. However, this does not mean that a given tile with a given rate of fall will carry just half as much water as it would were the fall twice as rapid. A fall of 0.1 of a foot per 100 feet is the least that is desirable for small tile or open ditches. In large tile or open outlet ditches it is often necessary to use as low a fall as 0.04 of a foot per 100 feet, or 2.0 feet per mile, but such a gradient is not self-cleaning. Four feet per mile is about the least gradient that will be self-cleaning at ordinary flow depths.

Soil and sub-soil—The more surface it has to wet and pass over, the more slowly water will flow in a given channel. In passing through soil, water flows through numerous small channels which are the connecting pore spaces between the soil grains whose surface forms the walls of these channels. The volume of pore space in clay soil is about one and one-half times as great as that in coarse sand but the **surface** of soil grains in clay is nearly four times as great as in coarse sand. That is why water flows through coarse sand much more rapidly than through clay. Betweeen these two soil types lie many others often found in agriculture. The rate of flow through these soils is as varied as is the character of the soils, hence the texture of the soil is very influential in determining the needed size and location of drains.

Rainfall.—After standing water from ponds and sloughs has run off through a new drainage system, the water that the system must be designed to carry off usually is only that from rain or snow. To be effective, drains must remove both the flood water on the surface and the excess water in the soil as quickly as possible after a single heavy rain, hence proper design of drains requires knowledge of the maximum intensity and the duration of the heaviest rains.

Purpose of the drainage system.—Drainage purely for permanent pasture, for grass crops, or for the coarser, shallower rooting forage crops may involve only an inexpensive surface drainage system, while potatoes and other tender truck crops call for a completeness of subdrainage the cost of which often seems prohibitive. There are all degrees in between, hence the end in view exerts marked influence in the proper design of farm drainage.

TILE DRAINAGE MOST EFFECTIVE

Open ditch systems are not, as a rule, real drainage systems. They act merely as flood-prevention or flood-removal systems. **Agricultural drainage is the removal of excess water from the soil. Tile drainage** is usually the only practical means of accomplishing this.

LOCATION OF THE DRAINS

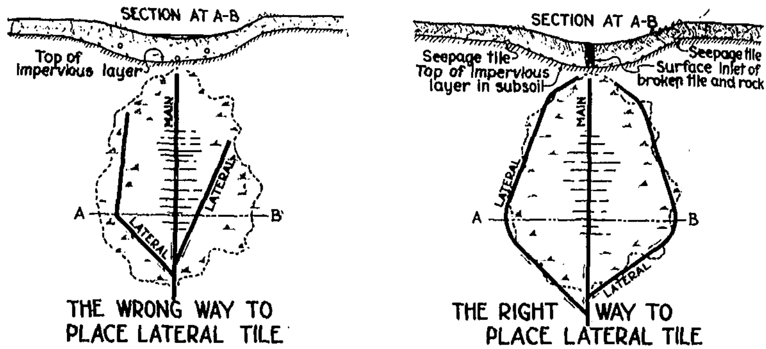


Fig. 1. Drainage of a pocket

General field systems.—On rolling land usually the drains may be located in the path of natural flow. Where pockets less than 150 feet wide exist, one line of tile through the center, the long way, is usually sufficient. Where a pocket exceeds 150 feet in width, it usually requires a seepage line around each side as well as a line through the center (see Fig. 1). For quick drainage of pockets, a surface inlet at the lowest point in the pocket is needed (see Figs. 2 and 3).

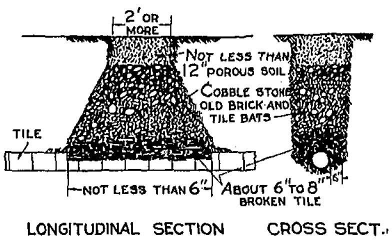


Fig. 2. Surface Inlet for Use in Cultivated Fields

Flat lands require parallel lines of small laterals at intervals over the entire area, the mains following the

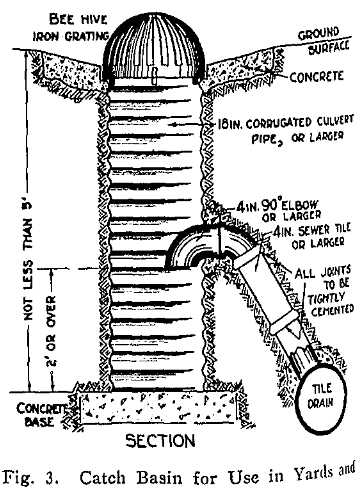


Fig. 3. Catch Basin for Use in Yards and Road Gutters

general paths of the surface flow. A system with short main and long laterals (up to 2,500 feet) is the most economical. The fewer the outlets the less will be the cost of maintenance.

Seepage.—Seepage areas result from an impervious layer of sub-soil checking the downward flow of the water, the pressure causing it to be discharged onto the surface at points on the lower slopes where the top soil is thin. Thus the low land is kept too wet for cultivation. In such cases tile lines should be run along the foot of the slope just above the wet area. These lines should be deep enough to catch the seepage water at the top of the impervious sub-soil over which it runs, before breaking through to the surface, and to carry it to the outlet drain across the lowland. The lowland in itself may have good natural drainage. Cutting off the seepage may be all that is needed. If one seepage line does not catch all the water, a second line a few feet from the first and parallel to it probably will (see Fig. 4).

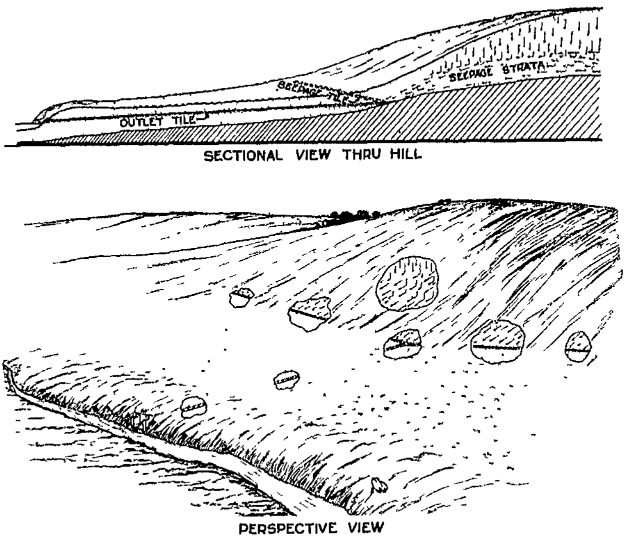


Fig. 4. Method of Draining Seeped Slopes

Depth and spacing of drains.—Depth and spacing of tile drains is governed by soil texture. In coarse soils the drains may be placed 4 or 5 feet deep and 200 to 300 feet apart. In sticky clay soils a depth of 2½ to 3 feet and a spacing of 50 to 60 feet is about right. In average loam soil the depth should be 3 to 3½ feet and the spacing 75 to 150 feet. As a rule, it is not profitable to place tile lines closer than 50 feet apart altho for special purposes and intensive cultivation it may be necessary. The ground water level between two adjacent tile lines is a curved line. The spacing and depth should always be such that the ground water table at its highest point between two drain lines will drop rapidly enough to prevent injury of the plants by the excess water.

In the case shown in Figure 5 the soil is fine sandy loam covered with a layer of peat from 1 to 6 feet thick. The original spacing (800 feet) was about right for grass crops but not for cultivated crops. The later spacing of 200 feet is suited to cultivated crops except in deep peat, where a spacing of 75 to 125 feet would be better.

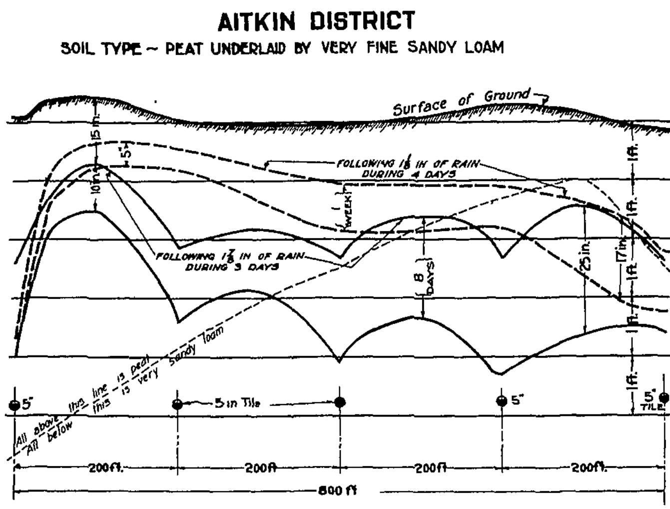


Fig. 5. Effect of Different Tile Spacings in Fine Sandy Loam Covered by a Thin Blanket of Peat

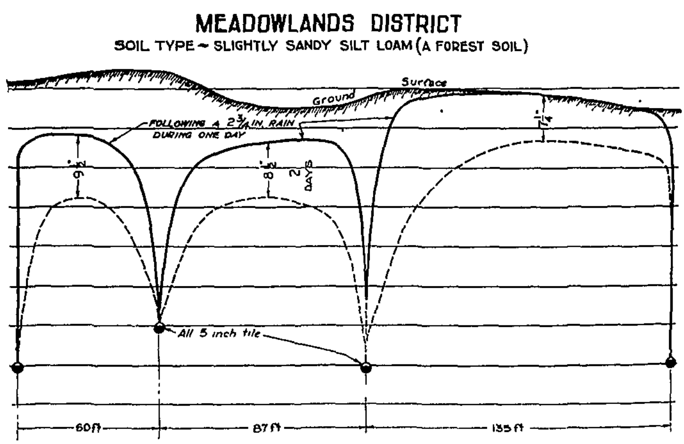


Fig. 6. Effect of Different Tile Spacings in a Slightly Sandy Silt Loam

The soil in the case shown in Figure 6 is a slightly sandy silt loam. Three different spacings—60, 90, and 135 feet—were used. The 60- and 90-foot spacings give sufficient drainage, while the 135-foot spacing is too wide for any except grass crops.

SELECTING DRAIN TILE FOR QUALITY

Listed sizes of drain tile refer to **inner** diameter. The important thing is to get **good** tile. Either clay or concrete tile may be good, and either may be poor. Therefore, when buying, it is good practice to require that the tile furnished shall meet the specifications laid down by the American Society for Testing Materials. These specifications cover uniformity of shape and size, thickness of walls, crushing strength, and absorptive capacity. There are three regular grades of tile: **farm drain tile,** formerly considered suitable for ordinary farm drainage in 6-inch size or smaller, and for depths of trench not exceeding 4 feet, but no longer produced by most makers of drain tile and no longer recommended for use in good drainage practice; **standard drain tile**, suitable for all drainage work in sizes 24-inch and under and for depths of trench not exceeding 8 feet; **extra quality drain tile** needed where the size exceeds 24 inches, and in all sizes when the depth of trench exceeds 8 feet. The Tile Laboratory, University Farm, St. Paul, makes standard tests free of charge, for any sample (5 tile of each size selected at random by purchaser or his agent from a given lot when unloaded from cars) sent to the laboratory, all carrying charges prepaid. The dealer should furnish such samples without charge.

A good tile, when tapped lightly with a hammer, will give a clear metallic ring; a poor or broken tile will give a "dead" sound. It is good practice to apply the "hammer test" to each tile when unloading from cars and again when laid, thus making it possible to eliminate all inferior or defective tile.

Clay tile.—There are two classes of clay tile, soft burned and vitrified. The latter is the higher grade. Either kind, well made, is satisfactory for average farm use. A good clay tile should be of uniform size, well burned, non-porous, free from grains of lime that cause the tile to disintegrate after wetting. In general, the harder burned the tile the higher the quality. A porous tile or one burned insufficiently disintegrates under frost action. Good clay tile are not affected by frost action, alkali salts, or peat acids.

Concrete tile.—Concrete tile made from good cement and clean sand and gravel, properly mixed and cured, are satisfactory and durable in soils free from alkali salts and acids. They should not be used in strong alkali or in high acid peat soils. Good concrete tile contain a large percentage of coarse aggregate, show water markings indicative of use of a liberal amount of mixing water, are dense walled and of uniform shape. Curing conditions for concrete are not usually such on the farm as will insure good tile; hence **the use of home-made tile is not recommended. Porous tile are without merit, as the joints provide all necessary opportunity for water to enter.**

Size of Tile

Size of tile required depends largely on the fall obtainable but somewhat, also, on the kind of soil and sub-soil and on the topography. An area with poor surface drainage usually requires larger tile than one with good surface drainage. When the soil is so open that most of the surface flood reaches the tile drains, or when surface inlets are used, ordinarily, larger tile are required.

As small tile are hard to lay accurately and as they are much more easily clogged by a small amount of dirt, sizes under 4-inch should not be used in farm drainage. Sizes under 5 inches are not recommended. It seldom pays on a single farm to use tile of greater diameter than 24 inches. Where larger sizes are needed it is usually preferable either to use two mains or to make the main an open ditch.

Table 1 gives the area, in acres, of average farm land that given sizes of tile for rates of fall ranging from 0.03 foot to 1 foot per 100 feet of length will drain. (Drainage coefficient ⅜ inch in 24 hours.)

Table 1

Area in Acres that Different Sizes of Tile will Drain with Different Rates of Fall

Fall in feet per 100 ft. of length	0.08	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.75	1.00
Inner diameter of tile	Area drained, to nearest acre									
Inches										
4	3	3	4	4	5	5	6	7	9	10
5	5	6	7	9	9	10	12	13	16	19
6	9	10	12	14	15	18	20	22	27	31
7	13	15	19	22	24	27	31	34	42	48
8	20	22	27	32	36	39	45	50	61	71
10	37	41	50	58	65	71	82	92	112	130
12	61	67	83	96	108	118	137	153	187	213
14	95	105	129	149	167	182	211	235	288	333
15	113	127	155	179	200	218	252	283	346	400
16	134	149	183	211	238	260	302	336	413	473
18	187	209	256	295	328	360	417	467	570	660
20	249	280	341	393	440	483	556	625	760	880
22	323	360	442	510	571	626	720	800	987	1,140
24	407	453	558	643	720	794	913	1,020	1,247	1,440

OPEN DITCHES SUITABLE FOR FARM USE

Usually on the modern farm, open ditches as a permanent type of improvement have little place. Frequently, however, depth, grade, and outlet conditions make necessary some open ditching in connection with tile. The purpose of such ditches is either to serve as outlet channels or as carriers of excess surface floods to relieve the tile drains of an overload and thus prevent smothering of crops.

Side slopes.—Steepness of side slopes of open ditches should be suited to the soil through which the ditch is dug. Care should be taken to make them smooth, so as not to obstruct the flow of water. Fibrous peat and hard-pan clay will often stand nearly vertical for years; whereas ordinary loam soils require slopes of 1½ feet horizontal run to 1 foot vertical rise (commonly called 1½ to 1 slopes), or flatter. Slopes in sandy soil or clear sand usually must be 2 or 3 to 1, or flatter. Slopes too steep for the type of soil are easily cut by flowing water, and earth thus washed loose tends to fill the ditch or to form mud banks that seriously obstruct the flow of the water and reduce the capacity of the ditch.

Intercepting ditches.—Where high land discharges considerable flood water onto lowland, it is often possible to cut off this flow with an open ditch at or near the foot of the hill and carry it away to some near by outlet stream, thus preventing the flooding of the lowland. These ditches are usually made wide and shallow. The excavated material is all thrown to the lower side, thereby increasing the capacity of the ditch. The bank and sides of the ditch are then smoothed off and sown to grass. As the capacity of such a ditch is required only occasionally and for short periods, no crops will be killed and no land is wasted by the ditch. Intercepting ditches should approximately follow the contour of the ground along the slope on which they are built. The rate of fall should not be great—just enough, if possible, for a flow that will be self-cleaning.

Auxiliary ditches.—Large open ditches across fields are inconvenient and wasteful, yet frequently where large areas of high land drain onto naturally fertile low land, the amount of low land may be too small to justify a tile large enough to carry the flood water from the high land. In such a case, a tile main may be laid large enough to take the ordinary underdrainage from the upland and the entire drainage from the low land. The surface flood from the high land may then be taken care of by an intercepting ditch of considerable size carried across the low land to an outlet and serving as an **auxiliary flood ditch.** The primary purpose of these auxiliary ditches is to aid in quickly removing surface floods, to prevent overloading the tile drains, and to prevent impounding flood water in depressions in the flat lowland. Such a ditch need be only deep enough to keep all the water moving. It will be used only occasionally and for short periods; hence it should be made wide and V-shaped, with flat slopes that may be farmed right across. The material from the ditch should be spread out thin over the adjacent field. In this way unsightly and inconvenient waste banks are eliminated and the low area protected and thoroly drained at low cost, without waste of land.

Over large areas of flat land it is often possible and desirable to connect into a chain the usual numerous shallow depressions, by such shallow V-shaped ditches, deepening them slightly, as they extend toward their final outlets (see Fig. 7).

These V-shaped ditches can be dug most cheaply with a regular road grader drawn by whatever type of power is available, but tractor power is the most satisfactory. In soils comparatively free from roots and stones, a drag grader does the work well. Small ditches of this type may also be made readily with a plow run successively in the

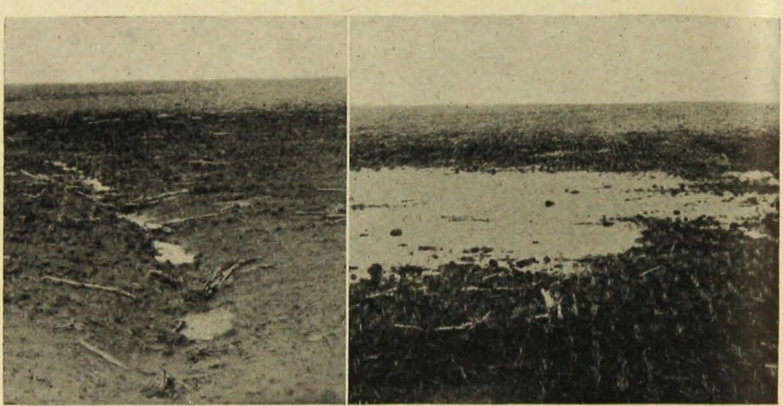


Fig. 7. V-Shaped Surface Flood Ditch
Left, a V-shaped flood ditch functioning after a rain; right, a condition which the flood ditch prevents—water standing on a crop after a rain.

same furrow, the crumbs and loose earth being quickly cleaned out with a shovel. Either the plow or the grader should be run always in the direction to throw the material to the down-hill side.

CONSTRUCTING TILE DRAINS

Method of staking.—It is here assumed that the tile lines have been staked according to the following method (see cover page). Starting at the outlet of the main, the line is measured carefully and marker stakes (about 2 feet long and 1½ inches or more wide) placed 100 feet apart on straight lines and 10 to 50 feet apart on curves, according to their sharpness. On each of these stakes its station number, that is, its distance in hundreds of feet from the lower end of the tile line, is plainly marked. A hub stake (a short stout stake with a square sawed top) is driven solid and nearly flush with the ground just in front of each marker stake. Exact levels are taken by the engineer on the tops of the hub stakes. From these the gradients of the tile lines are determined and the cuts from tops of hubs to finished grade at bottoms of trenches are worked out. The cuts are tabulated by line and station, points of change of grade and rates of grade being marked, and a copy given the tiler to guide him in setting the targets by means of which he digs his trenches to correct grade. Locations of surface inlets or catch basins, and the like, are plainly marked by special stakes.

Trenching by Hand

Hand tools (see Fig. 8).—Most of the spading is done with a tile spade. In very loose soil the solid blade is needed, but in most soils, the skeleton blade is handier, as it is lighter and the soil drops from it more readily.

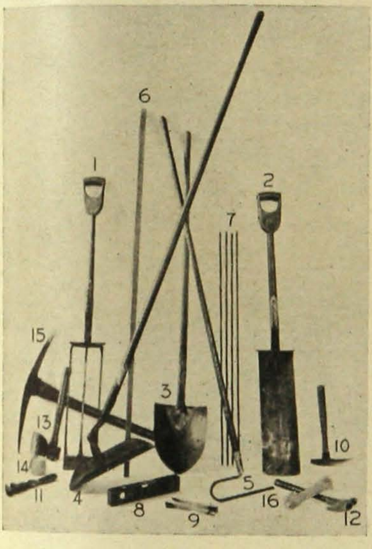


Fig. 8. Tools Used in Tiling by Hand

1. Skeleton blade spade
2. Solid blade spade
3. Long handled round-nosed shovel
4. Drain cleaner
5. Tile hook
6. Five-foot guage rod
7. Target rods
8. Carpenter's level
9. Six-foot zig-zag rule
10. Prospector's pick
11. Monkey wrench
12. Claw-hammer
13. Hand ax
14. Ball hard-twisted white cotton twine
15. Pickax
16. Small rope for guide line (100 feet)

Digging to guide line.—Digging must begin at the outlet and proceed up stream. The trench must be dug to straight lines and smooth curves. Top spading should be done to a guide line stretched along the stakes (see Fig 9). If the top spading lines up poorly, it is practically impossible to smooth up the line in later spadings. On curves the guide line, stretched reasonably tight past the regular stakes, should be drawn outward to a smooth curve between stakes and fastened by pegs (see Fig. 10).

Method of spading.—One should not set a tile spade square across the trench or attempt to take either a full-width or a very thick bite, as the side friction will be too great to break it loose readily. After the blade is settled to its full length, the handle should be thrust forward slightly to break the side bond before the spade is pried backward to lift out the slice (see Fig. 11).

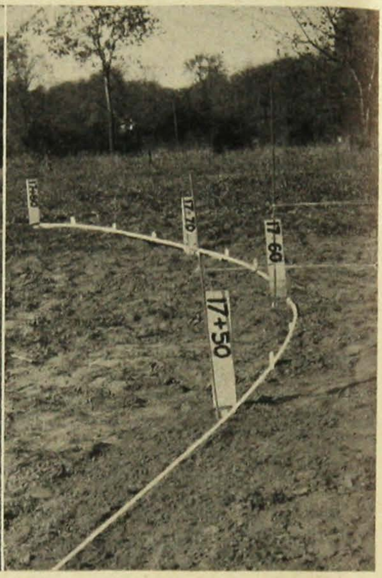


Fig. 9 (Left). Top Spading to Guide Line
Only the unskilled workman will try to dig the ditch straight without a line. Note that the workman faces the outlet and casts his material into a heap all on one side of the trench.

Fig. 10 (Right). Guide Line on Curve
Note the short pegs holding the line to a smooth curve.

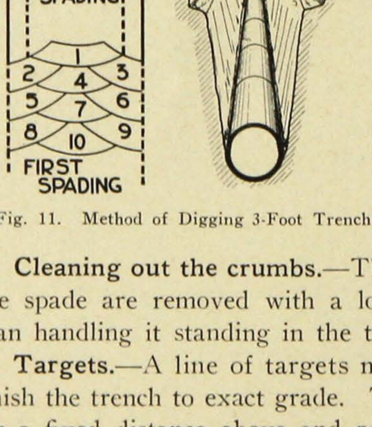


Fig. 11. Method of Digging 3-Foot Trench

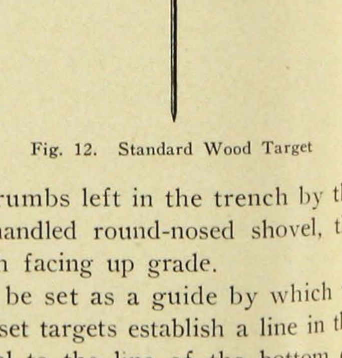


Fig. 12. Standard Wood Target

Cleaning out the crumbs.—The crumbs left in the trench by the tile spade are removed with a long-handled round-nosed shovel, the man handling it standing in the trench facing up grade.

Targets.—A line of targets must be set as a guide by which to finish the trench to exact grade. The set targets establish a line in the air a fixed distance above and parallel to the line of the bottom of the finished trench. The height of this line above the bottom of the trench should be convenient to the eye-height of the tiler, say 5 feet.

Setting targets with cut from hub stake less than five feet.—For convenience let 5 feet be assumed as the height the target is to be set above grade. The method is as follows (see Fig. 13).

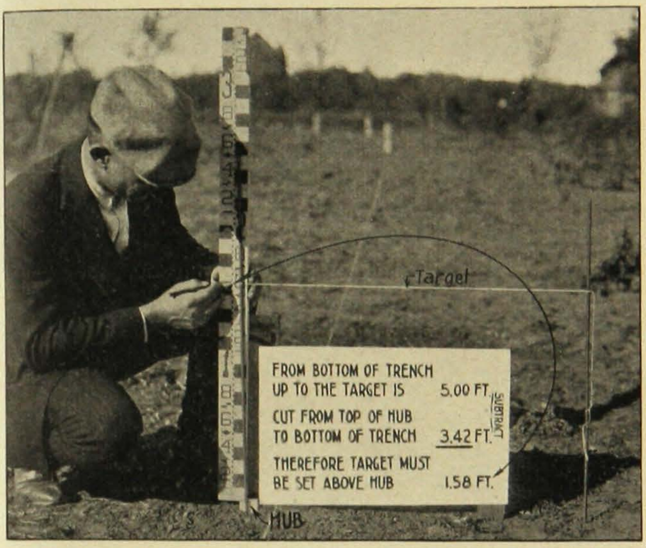


Fig. 13. Setting a White String Target 5 Feet Above Bottom of Trench

1. Subtract established cut at given station from 5 feet.

1. Drive a small iron rod ($^5/_{16}$ or ⅜ inch) or a stiff tall stake just back of or beside the hub on the outside and a similar rod square across the proposed trench from the first rod.

3. On the first rod measure up from top of hub the amount (1.58 feet) obtained in step 1 and tie a piece of hard twisted white cotton twine to the rod at this point. Stretch this twine across to the second rod as near level as the eye can judge, and tie it. A zigzag rule with feet and inches on one side and feet, tenths, and hundredths on the other is the handiest measure to use.

4. Level the string with a carpenter's level. Check the measured height (1.58 feet) on the first side. After adjusting this, check the leveling. Figure 12 shows another type of target in common use.

Number of targets needed.—Targets should be set at not less than 3 stakes along any given strip of continuous grade at any one time—5 or 6 is better. Each target must be set from the cut required at its own particular hub stake (see Fig 14). If the engineer's work and the target setting are both perfect, all the targets along any given grade will line up and be projected against the background as one line, and the line of sight along such a series of targets, as line AB

(Fig. 14). at all points will be just 5 feet above the proposed bottom of the finished trench.

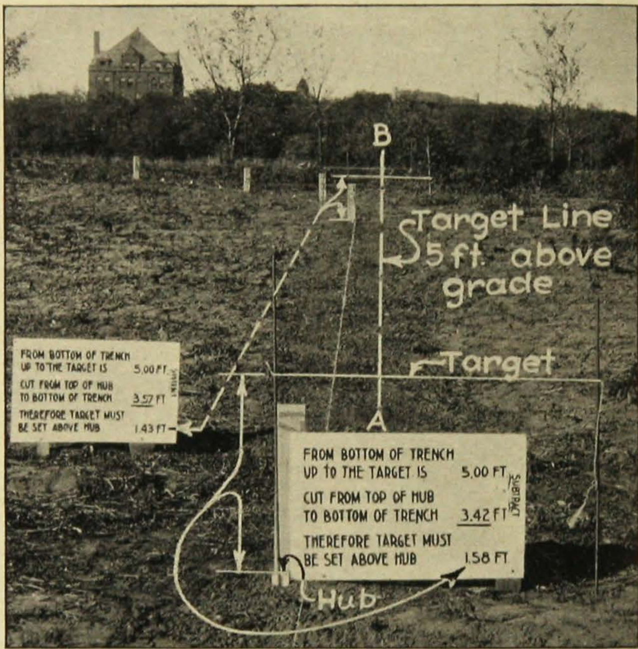


Fig. 14. Targets at Two Consecutive Stakes Establish the Line of Sight 5 Feet Above Grade

Correction of apparent errors in line of targets.—For several reasons a series of targets along a given stretch of grade may not line up perfectly. In such a case, assuming that the greater number of targets that do line are on the correct grade, move the others up or down until they come into line, being sure to keep all targets level. Before such adjustment, be sure that none of the hub stakes have been disturbed. If any great apparent error occurs at any stake, it is probable either that the recorded cut is wrong or that there is a mistake in the measured height of the target.

When cut exceeds five feet.—If the cut exceeds 5 feet, or the target height from grade, targets can not be set until the trench has been excavated below a cut of that amount. Then the rods holding the target must be driven slanting into the sides of the trench, 5 feet must be subtracted from the cut and the remainder measured down from the hub or from a level line set across the top of the hub.

Setting targets at change of grade.—The tiler works up grade from and facing the outlet, hence the target line guiding him is always down grade from him. Therefore, below the outlet or below a point of change of grade a target must be set, by eye, in line with those already set up grade from the point, so that the workman will always have below him a target line from which to check until he passes the second regular stake on a given grade (see Fig. 15).

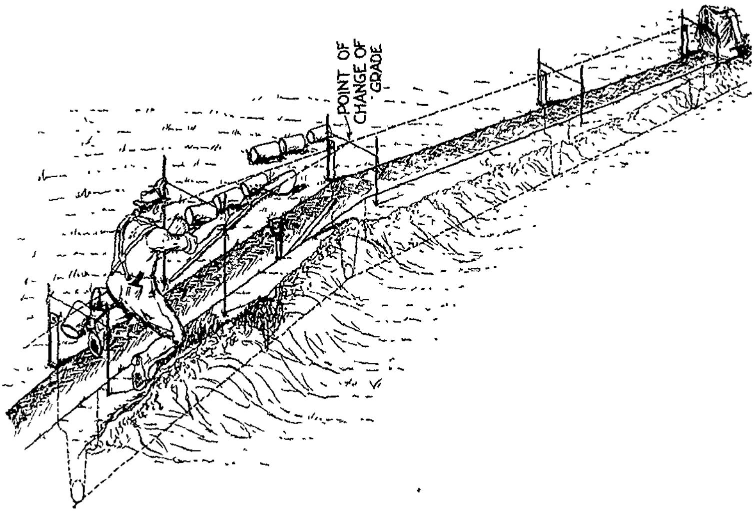


Fig. 15. Lining in Additional Targets Below Outlet or Point of Change of Grade

How to Use The Targets

Gauge rod.—Line AB, Figure 14, is a sighting line through all the targets on a given grade. With targets set 5 feet above the proposed bottom of the trench, when the top of a 5-foot stick held vertically with one end on the bottom of the trench lies in the line of the targets, the trench at that point is at proper grade. The tiler may thus test the grade of every foot of the trench. Many workmen use a notch in the handle of the drain cleaner at gauge height from its point instead of a separate staff, but in loose or soft ground the weight of the drain cleaner will settle its cutting edge enough to make serious error in testing the grade. Therefore, a slender wood staff with square sawed ends is better.

Bottoming the trench.—The bottom of the trench is finished with the crumber or drain cleaner, which is made in different sizes to fit the outside of tile of any size. The handle can be set at just the right angle to enable the tiler to control its motions exactly (see Fig. 16). If the bottom of the trench checks too high in any spot, the crumber should be placed snug against the bottom of the trench where the grade is correct, just back of the high spot, and drawn forward with this finished part of the trench as a guide, until the blade of the crumber cuts off the high spot much as a jointing plane trues up the edge of a board. One must plane just to grade and never cut too low.

If any spot is cut too low, this hollow should be filled back with well pulverized soil, which should be well tamped with the crumber and the bottom of the trench again planed to grade.

Fig. 16. Method of Finishing Tile Trench to Grade

Stays and Trench Braces

In trenches over 8 feet deep it is necessary to use staging and two or more lifts, the bottom man casting to the first staging from which another passes the soil to a second staging or to the top. In loose material or in clay liable to slip along cleavage lines or cracks, it is necessary in trenches over 6 feet deep to use plank stays and trench braces to prevent caving (see Fig 17).

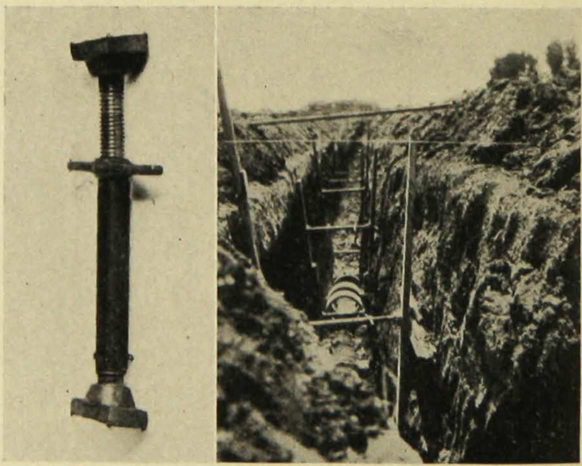


Fig. 17. Trench Braces and Plank Stays
Left, trench brace alone. Right, trench braces and plank stays in position in tile trench.

Trenching by Machine

Several power machines are made for tile trenching, almost any of which do satisfactory work within the limits of what they are built to do. These machines cost several thousand dollars; hence they are suited to ownership and operation only by contractors. On large farm drainage projects it is often profitable to employ a contracting concern owning and operating a power trencher.

Laying the Tile

The tile should be laid with tight joints to an even line that looks, before covering, like a continuous pipe (see Fig. 18). The tile should be kept laid up to within a few feet of the finished trench. If a tile does not fit tight against that previously laid, it should be turned on its long axis until the position is found in which it will do so. Each tile, as laid, should be given a smart tap by tile hook or heel to make it fit

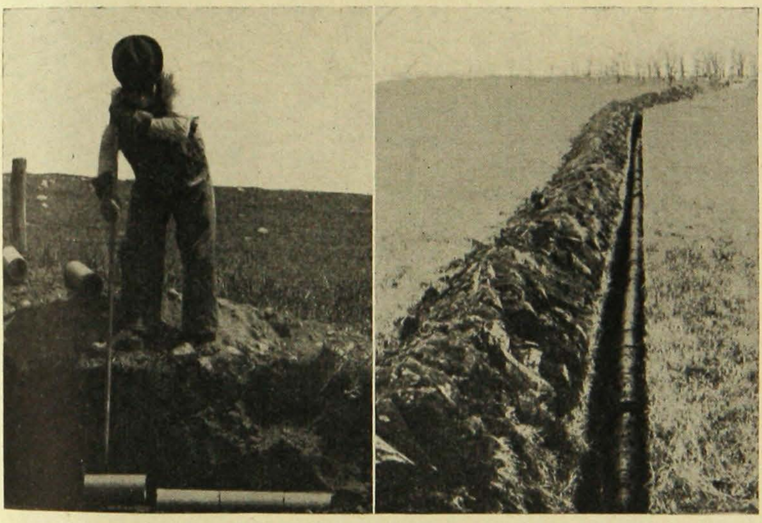


Fig. 18a. Laying Tile with Tile Hook—Sectional View

Fig. 18b. Line of Tile in Trench. Trench Ready to Blind

tightly against the last laid piece. (This should not be done with small concrete tile the ends of which are made nearly perfect, tending to make the joints too tight.) Where joints lie open more than $\frac{1}{8}$ inch in sandy or ordinary loam soils, they must be covered with broken pieces of tile (tilebats) grass clods, hay, or tar paper. Tile up to and including 8-inch may be laid readily either with the tile hook or by hand. Larger tile must be laid by hand, and sizes too large to be lifted readily must be handled by means of a rope, a derrick, or a suitable mechanical hoist. The tiler should reject all tile that are cracked, too soft, or so ill-shaped that a smooth line can not be obtained.

Making Junctions and Trimming Tile for Curves

For sizes of tile up to and including 12-inch, factory made junctions are obtainable, but the tiler should know how to make his own junctions by hand. To start the hole for a junction in a small tile, one may either chip it through with the point of a prospector's pick (No. 10, Fig 8) or he may use the face of the pick or of any light hammer as follows: Completely fill a sound tile with dry sand to prevent vibration, holding the tile between the knees with two small boards to keep the sand in. Then give a prolonged series of light taps in the same spot with the face of the hammer. A small hole will soon result without cracking the tile if care is used and the job is not hurried. To enlarge the hole, use a common monkey wrench just as one does a glass cutter in trimming the edge of a pane of glass. The same tool is best also for trimming the ends of tile to secure close joints on sharp curves.

Keeping Tile Clean

Keep tile clean while laying. Earth in a tile line attracts roots and may cause a stoppage. Earth is easily dumped out of small tile. With large tile, tie a large burlap swab to a short length of small rope and draw it forward through each newly laid tile.

Blinding the Tile

A new laid line of tile should be covered to a depth of from 4 to 6 inches close up to the end of any day's work to hold it in place against the action of the elements or other disturbance until the trenches are filled. This is called **blinding.** It is done by the tiler walking astride the trench and cutting down earth with a tile spade from both slopes below the surface. In blinding, be careful not to disturb the batted joints or the alignment of the tile. In tight soils a layer of several inches of coarse hay spread over the tile before blinding prevents joints from sealing and facilitates drainage.

Refilling Trenches

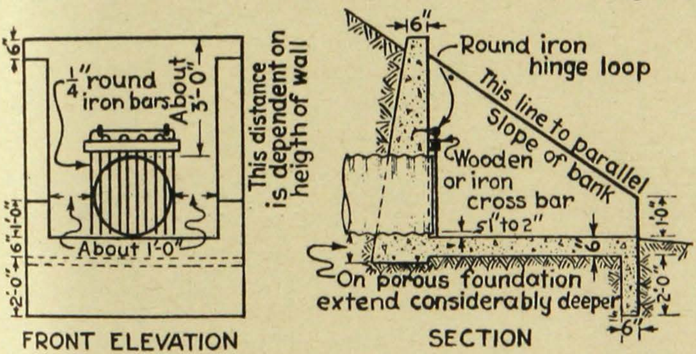
Refilling trenches may be done by hand with shovels, by plow (see Fig. 19), by scraper, by road grader drawn by tractor power, or by other special methods and devices. Short sections near buildings, fences, and other places inaccessible to teams and machinery must be filled by hand, as must also a short length of trench at the outlet to provide turning ground for teams and machinery.

Protecting Tile Outlets

The essential thing is to make protections permanent. If the tile line ends at or near the bottom of the outlet channel with little or no drop from the tile to the stream or but little side current in the stream to cause scouring and undermining, a cheap and satisfactory protection

Fig. 19. Refilling Trenches with Plow

is 15 or 20 feet of corrugated iron culvert of good grade at the tile outlet. The joint between the last tile and the culvert should be tightly cemented and the culvert itself should be laid on a firm bed of natural soil. A ring of ½-inch round iron rolled into the outer end of the culvert protects against crushing. Where there is a drop from the outlet of the tile to the bed of the outlet channel, the tile outlet should be protected with a head wall or bulkhead and apron (see Fig 20).



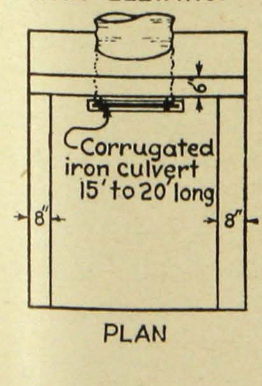


Fig. 20. Simple Plan of Outlet Bulkhead for Tile Line

A screen is necessary to keep out living creatures that are, otherwise, a dangerous cause of clogging. The screen may be of fine-mesh poultry netting or it may be a grating of slender iron bars spaced not over an inch apart. These bars may be set in the concrete of the bulkhead or in a frame so fastened that the whole grating may be removed to clean out the mouth of the drain and again replaced.

OBSTRUCTION OF DRAINS BY TREE ROOTS

Roots of willows and other water-loving trees growing in the vicinity of tile drains are likely to penetrate the drains and obstruct the flow, especially if the tile carries water far into the dry season. Such trees should be grubbed out, or all tile within 50 or 75 feet of them should be bell-ended sewer pipe and the joints tightly cemented with rich cement mortar.

VERTICAL DRAINAGE

Vertical drainage is the disposal of excess water through surface inlets into a pervious soil layer, as gravel or coarse sand, that is capable of taking considerable water rapidly and that itself has an outlet lower than the land to be drained. If such a layer lies within a short distance from the surface, say within 10 to 15 feet, it can be determined by boring a hole with a 6- or 7-inch post auger with extension handle. Lower a 5- or 6-inch tile into this hole (see Fig. 21). Do not drop the tile in, as they will break. If the pocket to be drained is in pasture or meadow, the tile can come to the surface and be capped with a grate; if in a cultivated field, cap, and cover with coarse gravel about

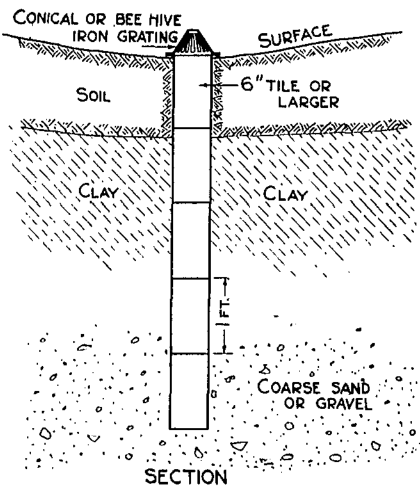


Fig. 21. A Vertical Drainage Well—Sectional View

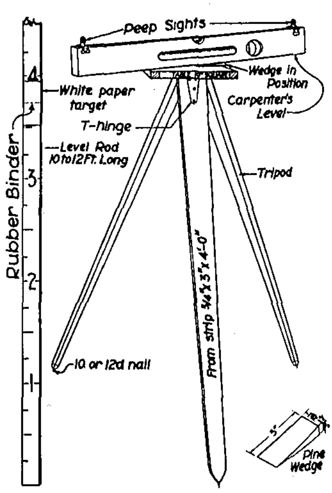


Fig. 22. A Simple and Inexpensive Farm Level

a foot below the surface. Vertical drainage will not work unless it leads into gravel or sand layers not already water-logged, and it is not recommended except where it is not economical to install a regular tile drainage system.

A FARM LEVEL

While the very accurate leveling required for systems of tile drains should be done by an experienced engineer, the farmer planning to put in open intercepting or auxiliary flood ditches or single, unattached lines of tile, will find it very convenient to be able, himself, to run approximate levels. A regular engineer's level for this purpose is an expensive instrument for him to buy and he would not know how to keep it in order; but Figure 22 shows a cheap leveling device that he can rig up himself at very slight expense. The carpenter's level should be a good 24-inch wooden one with an active bubble. The peep sights are not necessary, but are very convenient. They may be obtained thhrough your local hardware man for $2.00 or less. The small table, its tripod legs, and the wedges may be made of any good soft wood. The rod should be a strip of clean white pine about 1½ to 2 inches wide with the feet, half, and quarter feet marked on it in black lumber crayon.

A careful study of Figure 23 will make clear the system of leveling. It should be borne in mind that at least two readings must be taken (a backward sight on the last point and a forward sight on a new point) for each new position of the level. One should not try to take sights over 100 feet long with this type of level.

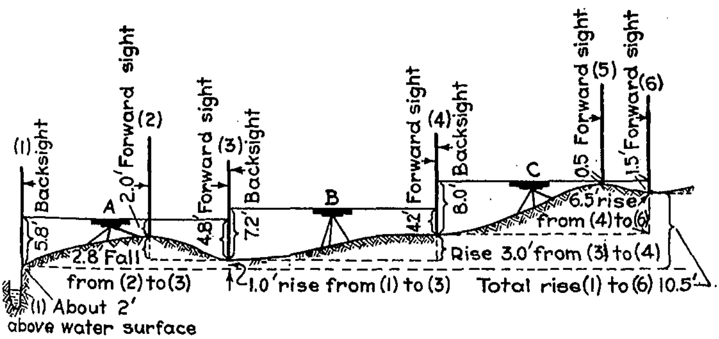


Fig. 23. Method of Running Approximate Levels

COST OF TILE DRAINAGE

The cost of any ordinary farm tile drainage system is made up of several distinct parts, as shown in Table 2.

Table 2

Cost of Tile Drainage on the Farm

Item	Approx. per cent of total cost	
	Rolling land	Flat land
Engineering and supervision	9	7
Tile	28	37
Freight on tile	7	9
Haul and distribution (hauling the tile from the railroad station and distributing it over the fields along the proposed tile lines)	6	6
Trenching, laying, and blinding the tile	45	36
Refilling trenches	4	4
Outlet protection	0.7	0.7
Miscellaneous minor items	0.3	0.3

Engineering and supervision.—Professional day rates and necessary incidental expenses.

Tile.—Ask you local lumber dealer or write the manufacturer. For approximate estimates, figure at $8.00 per ton. (For weights see Table 3.)

Table 3

Weights of Drain Tile

Inner diameter of tile, inches	4	5	6	8	10	12	14	16	18
Av. weight per foot, pounds	7	9	12	20	27	37	52	69	84

Freight on tile.—Ask your local railroad agent for rates.

Haul and distribution.—Actual cost, at local rates, of man and horse labor or truck operation; usually estimated as costs per ton mile.

Trenching, laying, and blinding.—Since this operation requires skilled labor, higher wages must be paid than for ordinary labor, the price being 50 to 75 cents per hour without board. A good tiler will make twice the speed of an ordinary laborer and do better work. The hours required by an experienced tiler, for trenching, laying, and blinding 100 linear feet of tile for sizes from 4 to 24 inches and for trenches from 3 to 12 feet deep is given in Table 4 and Figure 24 for average digging conditions. Average conditions occur most frequently in ordinary prairie soils except after protracted drouth or when the ground is frozen.

Refilling trenches.—This class of work does not require skilled labor. It is usually done by the farmer himself.

Table 4

Hours Required to Dig 100 Linear Feet of Trench for Sizes of Tile from 4-inch to 24-inch, and for Depth of Trench from 3 feet to 12 feet. (Average Digging)

Diameter tile, inches	Hours per 100 linear feet for depths of trench shown on next line									
	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.	10 ft	11 ft.	12 ft.
4, 5, & 6....	7.32	13.22	21.20	31.35	43.95	59.33	77.38	99.03	123.00	150.95
8........	9.57	17.45	27.22	40.98	55.87	74.08	96.23	121.42	150.47	183.17
10........	12.27	21.58	34.00	49.13	67.85	90.12	115.87	145.43	178.67	217.70
12........	15.02	26.12	40.27	58.67	80.65	106.13	135.97	169.67	208.73	251.50
14........	17.75	30.97	47.65	68.33	93.47	122.73	156.52	195.00	237.09	287.04
16........	20.62	35.52	54.62	78.18	106.32	139.18	177.02	220.72	268.12	322.15
18........	23.38	40.32	61.82	88.28	119.90	155.52	198.13	246.07	298.85	357.73
20........	26.55	45.32	69.28	98.63	133.32	173.67	220.25	272.02	329.88	395.45
22........	29.58	50.62	77.12	109.28	147.12	191.75	241.93	298.43	362.37	431.97
24........	32.90	55.68	84.70	120.12	161.77	209.32	264.25	325.50	393.73	469.55

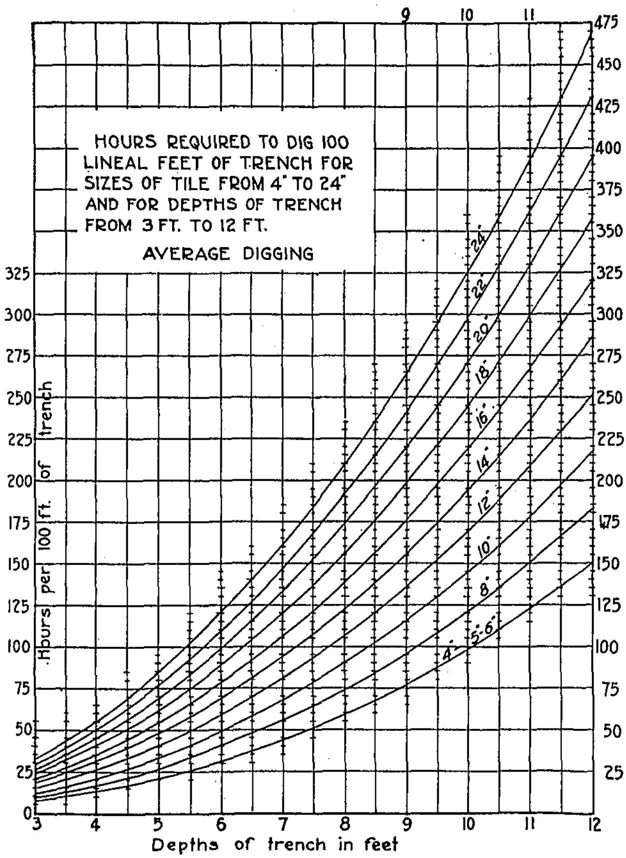


Fig. 24. Curves Showing Data in Table 4